

RESULTS

Results of the two series of balance studies are presented separately in Tables 1 and 2 and in combined form in Figures 1-3. Data from individual balance studies are presented in the Appendix.

STUDY 1

Data from 51 balance studies performed in study 1 are summarized in Table 1. As may be seen from Figure 1, urinary excretion of lead demonstrated only a modest increase with increasing intake of lead. The quantities of lead excreted in the urine were low in relation to those excreted in feces (Table 1). Fecal excretion of lead, on the other hand, was strongly correlated with intake (Fig. 2). Fecal excretion exceeded intake of lead in five balance studies. Retention of lead increased with increasing intake (Fig. 3).

STUDY 2

Because target levels of lead intake were applied irrespective of body weight, there was some overlap in the range of values of lead intake expressed per kg body weight at the intermediate and moderate intake levels (Table 2). As in study 1, the range of urinary excretions of lead was relatively small when compared with the wide range of intakes (Fig. 1). Fecal excretion of lead increased with increasing intake (Fig. 2). At low intakes of lead fecal excretion exceeded intake in four studies and mean values

Table 1. Summary of 51 lead balance studies performed in nine subjects (study 1)

	Mean	SD	Range
Age (days)	248		14-746
Intake ($\mu\text{g/kg/day}$)	10.29	5.46	1.72-22.61
Urinary excretion ($\mu\text{g/kg/day}$)	1.04	0.82	0.07-5.90 ¹
	(0.94)	0.45	(0.07-1.92)
Fecal excretion ($\mu\text{g/kg/day}$)	5.90	3.65	0.62-14.75
Absorption ($\mu\text{g/kg/day}$)	4.39	3.91	-3.12-12.43
Retention ($\mu\text{g/kg/day}$)	3.35	3.62	-3.82-11.29

¹ High value of 5.90 is more than 3 times higher than next lowest value and therefore may represent analytic error or contamination. Exclusion of this value yields mean, SD, and range given in parentheses on lower line.

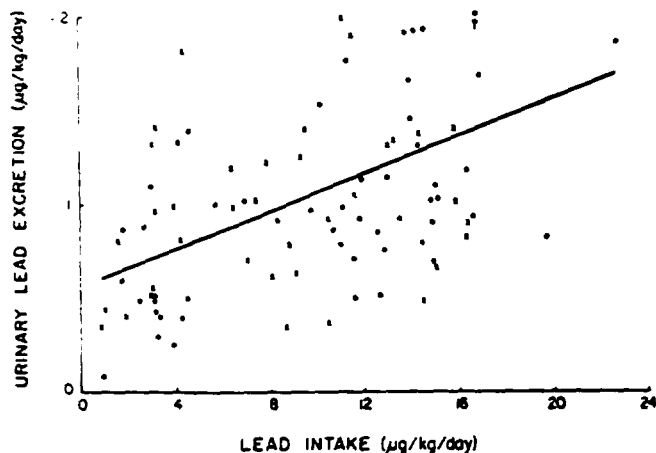


Fig. 1. Urinary excretion of lead in relation to lead intake. Each dot refers to the result of one metabolic balance in study 1 and each x refers to the result of one metabolic balance in study 2. In one metabolic balance (arrow) urinary excretion was 5.90 $\mu\text{g/kg/day}$. The calculated regression ($y = 0.0493x + 0.554$; $r = 0.381$) is included.

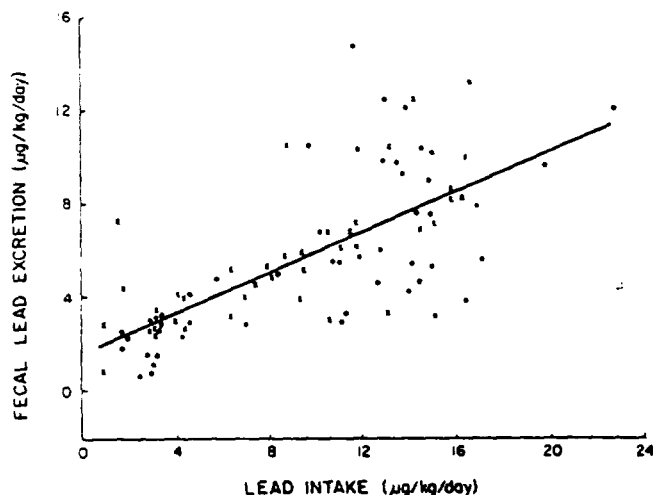


Fig. 2. Fecal excretion of lead in relation to lead intake. Symbols are as in Figure 1. The calculated regression ($y = 0.443x + 1.545$; $r = 0.710$) is included.

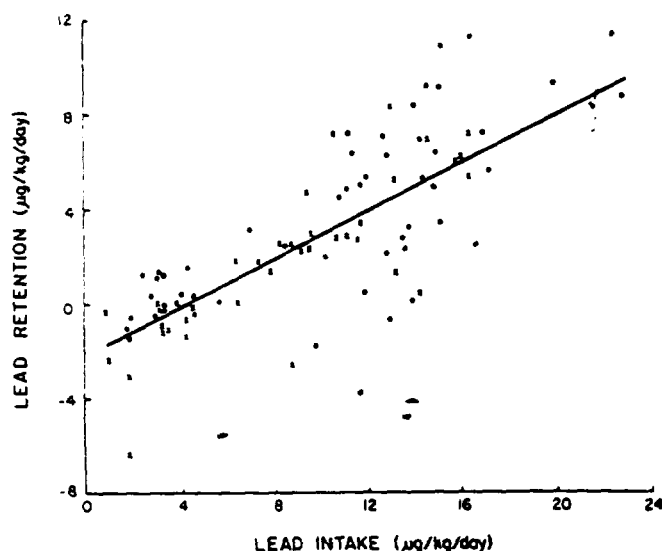


Fig. 3. Lead retention in relation to lead intake. Symbols as in Figure 1. The calculated regression ($y = 0.509x - 2.110$; $r = 0.755$) is included.

for net absorption and net retention were negative. At intermediate and moderate intakes of lead, net absorption and net retention were positive in all but one of the balance studies.

COMBINED DATA

Lead Intake. For all 89 balance studies intake of lead averaged 9.44 $\mu\text{g/kg/day}$ (SD 5.27, range 0.83-22.61). Because it seemed possible that the diets consumed immediately before a balance study might have a carry-over effect on the balance study, an attempt was made to control lead intake during at least the 3-day period preceding each balance study. Intake of lead during the 3-day prebalance periods averaged 8.44 $\mu\text{g/kg/day}$ (SD 5.55). Thus, prebalance intake of lead averaged 1.01 $\mu\text{g/kg/day}$ (SD 3.35) less than intake during balance studies.

Urinary Lead Excretion. Mean urinary excretion was 1.02 $\mu\text{g/kg/day}$ (SD 0.68, range 0.07-1.98 with the exception of one value of 5.90). Urinary excretion increased with increasing intake ($r = 0.381$; $P < 0.001$) (Fig. 1). Urinary excretion accounted only for a small portion of total excretion. There was no significant change in urinary excretion with age.

Fecal Excretion and Absorption of Lead. The correlation between fecal excretion and intake of lead was significant ($r = 0.710$; $P < 0.001$) (Fig. 2). It should be noted that fecal excretion of lead exceeded intake in 7 of 28 studies with lead intakes less than $5 \mu\text{g/kg/day}$ and in only 3 of 61 studies at higher intakes.

Net absorption of lead (micrograms per kg per day), calculated as intake minus fecal excretion, was correlated with intake of lead ($r = 0.786$; $P < 0.001$). Expressed as percentage of intake, absorption averaged 26.2% and was correlated ($r = 0.431$; $P < 0.001$) with lead intake. Because extremely low dietary intakes of lead are difficult to achieve except under experimental conditions, we have arbitrarily divided balance studies into those with intakes below and those with intakes above $5 \mu\text{g/kg/day}$. Mean absorption in 28 balance studies with lead intakes below $5 \mu\text{g/kg/day}$ was $0.24 \mu\text{g/kg/day}$. In 61 balance studies (10 subjects) with lead intakes above $5 \mu\text{g/kg/day}$, mean absorption was $5.31 \mu\text{g/kg/day}$, representing 41.5% of lead intake.

Retention. Mean retention was $2.69 \mu\text{g/kg/day}$ (SD 3.56), equivalent to 11.3% of intake. The relationship between intake and retention of lead was highly significant whether expressed in micrograms per kg per day ($r = 0.755$; $P < 0.001$) (Fig. 3) or as percentage of intake ($r = 0.507$; $P < 0.001$). Retention was negative (i.e., total excretion exceeded intake) in 23 studies, of which 19 occurred at intakes below $5 \mu\text{g/kg/day}$ and 4 occurred at higher intakes. With intakes of lead greater than $5 \mu\text{g/kg/day}$, mean retention was $4.16 \mu\text{g/kg/day}$, equivalent to 31.7% of intake. With intakes less than $5 \mu\text{g/kg/day}$, mean retention was $-0.48 \mu\text{g/kg/day}$, equivalent to -33.1% of intake.

Retention, whether expressed in absolute terms or as percentage of intake, did not change with age. Regressions of lead retention on lead intake (micrograms per kg) were calculated for individual subjects who had had four or more balance studies. These subject-specific regressions were homogeneous with respect to slope and intercept. Thus, the study did not provide evidence of a significant difference between individual infants in the relation of lead intake to lead retention.

Calcium Intake and Lead Balance. Calcium intake and lead intake were not significantly correlated. A significant inverse relationship was demonstrated between calcium intake and absorption of lead expressed either as micrograms per kg per day ($r = -0.240$; $P < 0.05$) or as percentage of intake ($r = -0.277$; $P < 0.01$). Similarly, calcium intake was inversely correlated with retention of lead expressed as micrograms per kg per day ($r = -0.279$; $P < 0.01$) or as percentage of intake (Fig. 4) ($r = -0.284$; $P < 0.01$).

DISCUSSION

Animal studies have indicated that younger animals absorb and retain a greater percentage of ingested lead than do older animals. Kostial *et al.* (10) fed $2 \mu\text{Ci } ^{210}\text{Pb}$ contained in a formula based on cow milk to 5-day to 7-day-old rats. After 80 hr, 53.4% of the administered dose was retained in the carcass (excluding the gastrointestinal tract). They stated that similar studies of adult rats demonstrated only 1% retention. Forbes and Reina (6) measured the activity of ^{210}Pb in the gastrointestinal tract after administration (by gavage) of a dose of the radioactive material. The loss of ^{210}Pb in feces was not determined. The activity of ^{210}Pb in the contents of the gastrointes-

Table 2. Summary of 33 lead balance studies in six subjects studied at each of three different lead intakes (study 2)

	Lead intake		
	Low (13) ¹	Intermediate (12) ¹	Moderate (13) ¹
Age (days)	214	213	235
Intake ($\mu\text{g/kg/day}$)			
Mean	2.83	8.70	13.28
Range	(0.83-4.31)	(6.31-11.59)	(8.60-16.34)
Urinary excretion ($\mu\text{g/kg/day}$)	0.89	1.09	0.98
Fecal excretion ($\mu\text{g/kg/day}$)	3.29	5.21	7.91
Absorption ($\mu\text{g/kg/day}$)	$-0.46 = 2.83 - 3.29$	3.49	5.37
Retention ($\mu\text{g/kg/day}$)	$-1.35 = -0.46 - 0.89$	2.39	4.39

¹ Number of studies.

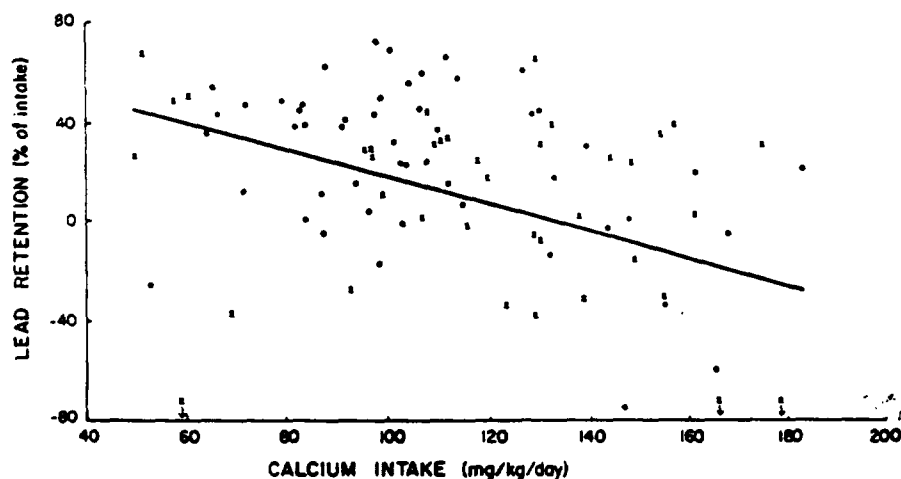


Fig. 4. Lead retention (expressed as percentage of lead intake) in relation to calcium intake. Symbols as in Figure 1. In three Balance studies (arrows) lead retention was (in ascending order of calcium intake) -245%, -167% and -374% of intake. The calculated regression ($y = -0.547x + 72.57$; $r = -0.284$) is included.

tinal tract 8 hr after administration accounted for only 10-17% of the dose in 16-day to 20-day-old pups but accounted for 85% in 32-day-old pups.

The data of Kehoe (8) indicate that an average of about 10% of ingested lead is absorbed by the human adult. This finding has been corroborated more recently by Hursh and Suomela (7) with the use of radioactive isotopes (^{210}Pb) and by Rabinowitz *et al.* (15) using stable isotopes of lead. Few data are available concerning infants and children. Alexander *et al.* (1) have reported results of 11 balance studies carried out with eight subjects ranging in age from 3 months to 8 years. With intakes averaging 10.6 $\mu\text{g/kg/day}$ (range approximately 5-17 $\mu\text{g/kg/day}$), absorption averaged 53% of intake and retention averaged 18% of intake.

The present report concerns metabolic balance studies with infants and young children and includes results of two similar studies. Because certain precautions must be taken to maintain intakes of lead below 5 $\mu\text{g/kg/day}$, it seems likely that most infants and small children not under special study conditions receive intakes greater than this value. We have therefore analyzed separately the data from balance studies with intakes less than 5 $\mu\text{g/kg/day}$. When intakes of lead exceeded 5 $\mu\text{g/kg/day}$ in the present study, net absorption averaged about 42% of intake and retention averaged 32% of intake. Thus, our results are in general agreement with data from animal studies and corroborate to some extent the findings of Alexander *et al.* (1) from a small number of studies of infants and children combined. There is little question that infants and young children absorb and retain a greater percentage of ingested lead than has been reported for adults.

The balance technique does not take into account non-dietary intakes and excretions other than those with urine and feces. Although unmeasured losses of lead (e.g., with sweat) are likely to be negligible, intake of lead in inspired air may be substantial. In the present studies lead content of air was monitored and was found to be uniformly low. The estimated intake of lead by inhalation was less than 0.1 $\mu\text{g/kg/day}$.

It is worth noting that absorption and retention of lead, expressed as percentage of intake, increased significantly with increasing lead intake. These relationships are plausibly explained by relatively high fecal excretion of endogenous lead. The measured apparent retention thus represents a composite of true absorption and endogenous fecal excretion. At low intakes of lead, endogenous fecal excretion may exceed intake and "negative" apparent absorption (and retention) may result. On the other hand, at high intakes, apparent absorption approaches true absorption.

To the extent that the zero intercept of the regression of fecal lead excretion on lead intake provides an estimate of endogenous fecal lead excretion, this value is 1.54 $\mu\text{g/kg/day}$ (Fig. 2). Tracer studies have indicated that endogenous fecal excretion of lead by adult subjects is in the neighborhood of 0.07-0.13 $\mu\text{g/kg/day}$ (15). There is, therefore, a suggestion that infants and young children not only absorb lead more efficiently but also excrete it more rapidly than do adults.

An inverse relationship was demonstrated between intake of calcium and absorption and retention of lead (Fig. 4). It should be noted that the bulk of dietary calcium was closely paralleled by intake of phosphorus, of magnesium, and of other (unmeasured) components of milk and formula. Nevertheless, animal studies suggest that calcium is of primary concern.

In the rat, low dietary intake of calcium leads to increased retention (2, 11, 12, 14, 16) and toxicity of lead (12, 16). Low dietary intake of phosphorus enhances the effect of a low

calcium diet, whereas low dietary intake of phosphorus alone has little effect (2, 14). Conversely, high dietary intake of calcium diminishes lead absorption (2). Calcium and phosphorus act primarily on intestinal absorption of lead (2, 11, 14), although low dietary intake of calcium also alters metabolism of lead in bone (14).

CONCLUSION

The metabolic balance technique was used in this study of infants and children less than 2 years of age to determine net absorption and retention of lead. Milk or formula and commercially prepared foods were fed. With the exception of studies in which intakes of lead were so low that they were considered unlikely to occur under normal circumstances (i.e., less than 5 $\mu\text{g/kg/day}$), net absorption averaged 42% of intake and net retention averaged 32% of intake. Absorption and retention of lead accounted for greater percentages of intake of lead in this study of infants and young children than has been reported in studies of older subjects. Absorption and retention of lead were inversely correlated with calcium intake.

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- Analyses in our laboratory indicate that lead content of commercially prepared strained and junior foods marketed for infants is generally less now than at the time of initiation of this study.
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APPENDIX

Subject Number	Age (days)	Body Weight (gm)	Lead Intake (ug/kg)	Lead Excretion Fecal (ug/kg)	Lead Excretion Urinary (ug/kg)	Calcium Intake (mg/kg)	Subject Number	Age (days)	Body Weight (gm)	Lead Intake (ug/kg)	Lead Excretion Fecal (ug/kg)	Lead Excretion Urinary (ug/kg)	Calcium Intake (mg/kg)
2179	14	3475	2.99	0.75	1.09	81	2287	202	6975	13.85	12.07	1.65	147
2179	29	3910	2.66	1.51	0.87	86	2179	203	7895	12.94	3.34	1.30	128
2179	42	4255	3.20	3.06	0.28	87	2285	210	8170	13.72	9.25	1.19	107
2179	56	4520	3.03	1.13	0.51	83	2290	212	8100	16.20	8.27	0.83	107
2179	70	4955	3.17	1.49	0.42	83	2152	216	8350	7.84	5.25	1.22	119
2179	84	5485	2.42	0.62	0.49	65	2179	217	8050	13.17	10.50	1.32	99
2289	72	5390	13.43	9.76	0.91	183	2288	216	9940	12.69	6.02	0.51	79
2159	83	4455	0.94	2.81	0.45	59	2285	224	8485	14.13	5.34	1.91	92
2289	86	6030	12.94	12.45	1.14	167	2290	226	8120	9.47	5.17	1.38	130
2159	98	4795	0.83	0.81	0.35	68	2285	238	8350	16.32	3.89	1.14	100
2289	100	6360	10.11	6.67	1.51	161	2291	243	9805	1.87	2.28	0.07	53
2289	114	6670	11.63	14.75	0.70	154	2288	244	10280	11.13	2.92	0.99	111
2159	118	5030	9.28	3.94	0.62	60	2287	245	7525	17.01	5.58	5.90	103
2151	118	6025	11.59	7.12	1.05	175	2290	247	8540	11.43	6.80	1.87	116
2150	119	6570	1.72	1.89	0.85	165	2285	252	8600	12.57	4.60	0.83	113
2285	126	6800	13.96	4.21	1.47	126	2291	257	9900	3.96	3.30	0.25	71
2289	128	6850	8.34	4.95	0.91	139	2287	258	7800	4.56	4.10	0.50	103
2159	132	5245	10.43	6.79	0.92	50	2288	258	10425	12.81	9.93	0.75	132
2150	133	6825	1.71	2.42	0.59	146	2290	268	8725	3.14	3.36	0.96	128
2151	133	6355	9.35	5.79	1.24	143	2291	271	9860	4.23	2.36	0.40	64
2290	135	7310	9.75	10.49	0.97	98	2287	272	7760	4.57	2.93	1.39	114
2152	139	6745	14.94	9.10	0.65	153	2288	272	10380	11.63	6.10	0.50	97
2179	140	6805	1.78	4.34	0.41	166	2285	273	8930	6.91	2.81	1.02	82
2285	140	7140	14.48	10.28	1.92	111	2290	282	8530	4.31	2.61	1.81	114
2159	146	5385	15.30	6.98	0.48	57	2287	286	8080	14.98	10.40	1.08	102
2151	146	6600	15.74	8.21	1.39	156	2288	286	10965	11.90	5.72	0.91	106
2150	147	7095	2.97	2.86	0.49	131	2288	296	8880	3.18	2.93	1.32	123
2290	149	7335	15.09	3.19	1.02	97	2287	300	8230	14.79	9.00	1.01	101
2152	153	6840	14.17	12.38	1.36	160	2288	307	11150	11.30	3.32	1.74	114
2159	153	5410	10.55	3.01	0.37	51	2287	321	8660	14.83	7.52	0.92	128
2179	154	7160	1.72	7.33	0.81	178	2288	342	11500	10.97	5.36	0.78	129
2151	160	6925	15.77	8.61	1.05	131	2288	373	11395	2.92	2.62	0.53	129
2150	161	7040	3.20	2.88	0.41	143	2288	387	11765	3.84	3.03	0.99	128
2152	167	7440	3.06	2.61	1.41	154	2288	401	11875	6.31	3.17	1.31	95
2179	168	7590	6.96	3.99	0.70	109	2288	415	11955	6.39	5.12	1.19	106
2290	170	7235	14.22	7.73	1.31	109	2288	429	12230	8.60	5.75	0.34	95
2151	174	7315	4.16	3.95	0.82	148	2288	443	12295	8.74	10.44	0.77	93
2152	174	7675	2.88	2.32	0.51	137	2288	457	12325	11.00	6.19	1.98	96
2288	174	9210	14.47	4.68	0.80	87	2286	648	10371	22.61	12.06	1.88	92
2179	182	7685	7.35	4.57	1.03	157	2286	691	10890	11.83	10.27	1.12	96
2285	182	7950	14.99	5.28	0.67	106	2286	704	11020	5.67	4.66	1.00	83
2290	184	7640	10.75	5.50	0.85	91	2286	718	11335	16.83	7.92	1.69	66
2151	188	7420	4.04	4.02	1.33	138	2286	732	11170	19.73	9.64	0.82	71
2290	198	7655	16.34	10.05	0.89	111	2286	746	11255	16.55	13.15	0.92	94
2152	202	7975	8.03	4.85	0.63	110							

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Lead
metabolic balance studies

Absorption and Retention of Lead by Infants

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Summary

Eighty-nine metabolic balance studies were performed with 12 normal infants ranging in age from 14-746 days. Intake and fecal and urinary excretions of lead were determined and net absorption and net retention were calculated. Subjects were fed milk or formula and commercially prepared strained foods. Intakes of lead ranged from 0.83-22.61 $\mu\text{g/kg/day}$ with a mean of 9.43 $\mu\text{g/kg/day}$. Urinary excretion averaged 1.02 (SD 0.68) $\mu\text{g/kg/day}$ and was positively correlated with lead intake (Fig. 1). Fecal excretion was highly correlated with intake of lead (Fig. 2); fecal excretion exceeded intake in 10 studies. In 61 balance studies with lead intakes greater than 5 $\mu\text{g/kg/day}$, net absorption averaged 41.5% of lead intake and net retention averaged 31.7% of intake.

Retention of lead was highly correlated with lead intake (Fig. 3). Urinary plus fecal excretion of lead exceeded intake in 19 of 28 balances in which lead intakes were less than 5 $\mu\text{g/kg/day}$. Absorption and retention of lead were inversely correlated with intake of calcium (Fig. 4). Absorption and retention of lead accounted for greater percentages of intake of lead in this study of infants and young children than have been reported in studies of older subjects.

Speculation

Highly efficient absorption and retention of ingested lead by young children may be partly responsible for the high prevalence of lead intoxication in this age group.

In 1971 an *ad hoc* committee of the Bureau of Community Environmental Management, PHS (9) suggested 300 $\mu\text{g/day}$ for children as the daily permissible intake of lead from all sources. Children 1-3 years of age were specifically included. The daily permissible intake was based, in part, on the assumption that 90% of ingested lead would be excreted—an assumption based on extrapolation from data concerning adults.

However, it is known that suckling rats absorb a greater percentage of ingested lead than do older rats (6, 10). In addition, Alexander *et al.* (1) have reported data from 11 metabolic balance studies with subjects less than 8 years of age, including six studies with three subjects less than 2 years of age. As estimated from the figures included in the publication, these studies indicated that considerably less than 90% of ingested lead was excreted.

The present study was undertaken to establish the extent of absorption and retention of lead by infants and young children under circumstances in which lead ingested with food constituted the major source of lead exposure. The metabolic balance technique was utilized to determine intake, urinary excretion, and fecal excretion of lead. From these measurements, net absorption and net retention were calculated. Lead intakes similar to those supposedly occurring under ordinary circumstances were achieved by feeding milk or formula and other foods (beikost). No lead was added to foods nor were any special diets used.

MATERIALS AND METHODS

STUDY DESIGN

The metabolic balance studies were 72 hr in duration, usually with 11 days between the last day of one balance study and the first day of the next. In a few instances, more than 18 days elapsed between studies. When the diet was altered to provide a new level of lead intake, an adjustment period of no less than 11 days was interposed.

In the case of foods provided by us, the mother was asked to save all empty or partially empty containers and these were collected from the family at the time of the next delivery. The returned containers were weighed to determine the quantity of food consumed.

Two separate studies were conducted. These differed slightly in experimental design and in the extent of control of lead intake between balance studies. In study 1, three to eight balance studies were performed with each of nine infants. Lead intake varied among infants, but in the case of a specific infant intake was maintained at the same level for all balance studies or changed no more than once. Between balance studies choices of commercially prepared strained foods by older infants (over 6 months of age) were not controlled except during the 3 days immediately preceding a study. Differences in lead intakes from one subject to another, or in some cases in the same subject at different times, resulted primarily from differences in lead content of various commercially prepared fruits and juices.

In study 2, each of six infants (three infants had also participated in study 1) consumed, in randomized order, diets providing low, intermediate, and moderate intakes of lead. These diets were consumed during and also between balance studies. At each level of lead intake, two balance studies (three balance studies at low intake in one infant and at moderate intake in another) were performed consecutively.

The following target levels of lead intake were set: low, 30–40 $\mu\text{g}/\text{day}$; intermediate, 70–80 $\mu\text{g}/\text{day}$; and moderate, 120–130 $\mu\text{g}/\text{day}$. To achieve these intakes a number of food items in addition to milk or formula were selected according to both lead content and anticipated acceptance by the infant. These were supplied to the family. No other foods were to be fed.

SUBJECTS

Twelve infants and young children (six males and six females) were studied between July 1974 and December 1975. In most cases the parents were students or faculty of the University of Iowa. Ages of the subjects at the time of study ranged from 14–746 days (Appendix). All subjects were in good health and demonstrated rates of gain in weight and length above the 10th percentile of the selected reference data (4). The study was explained in detail to one or both parents by one of us (B.B.E.) and written consent was obtained.

PROCEDURES

Subjects were admitted to the Pediatric Metabolic Unit for performance of the metabolic balance studies. Concentrations of lead and of various nutrients in milk, formula, and beikost

were determined. The quantity of each food consumed was recorded. From lead concentrations of the foods and the weights of foods consumed, intakes of lead were calculated. Urine and feces were collected using previously described techniques (5). Air was sampled (22 liters/min for 60 min) in the Pediatric Metabolic Unit and in the homes of six subjects using standard equipment and procedures (13). In each instance, lead content was less than 0.2 $\mu\text{g}/\text{m}^3$ of air.

Efforts were made to avoid contamination in collecting and handling of specimens of urine and feces. Collection vessels and storage flasks of borosilicate glass were washed with lead-free nitric acid (20% v/v) and rinsed thoroughly with glass-distilled water. Urine specimens were transferred at frequent intervals to the flasks, which were kept covered with plastic wrapping and stored in a refrigerator during the collection period.

Determinations of lead concentration were carried out in duplicate or triplicate with samples of food and feces and with some but not all samples of urine. Samples of food, feces, and dust were dried at 100° and dry-ashed at 400° overnight. The ash was dissolved in 1N nitric acid. Urine samples were brought to pH 2.8 by adding nitric acid. Standard solutions containing 0.2, 0.4, and 0.6 ppm lead (as the nitrate) were prepared with 0.01 N nitric acid from stock standard solution containing lead in a concentration of 1 g/liter. Samples (i.e., dissolved ashes or acidified urine), standards, and distilled water blanks (50 ml each) were subjected to solvent extraction using 5.0 ml freshly prepared 2% (w/v) aqueous ammonium pyrrolidine dithiocarbamate and 5.0 ml methylisobutyl ketone (3). Lead concentration was determined using a Perkin-Elmer model 303 atomic absorption spectrophotometer. All chemicals were reagent grade and contained less than 10 ppb lead by analysis.

Seven samples of formula and three samples of whole cow milk were analyzed in duplicate. Mean concentrations of lead were 18 $\mu\text{g}/\text{kg}$ (range 15–20) in formula and 10 $\mu\text{g}/\text{kg}$ (range 7–15) in milk. Fifty-six duplicate samples of beikost were analyzed. The technical error was 4.70 $\mu\text{g}/\text{kg}$ (coefficient of variation 9.1%). In 25 instances the difference in lead concentration between duplicates was 3 μg or less per kg of food. In 89 duplicate determinations of fecal lead content the technical error was 27.0 $\mu\text{g}/\text{kg}$ (coefficient of variation 5.9%). In 17 duplicate determinations of urinary lead content the technical error was 2.22 $\mu\text{g}/\text{liter}$ (coefficient of variation 13.8%).

Recoveries of lead added to foods, feces, and urine averaged 98.2% (SD 8.0%) for 50 foods; 99.9% (SD 9.5%) for 60 fecal samples, and 101.0% (SD 4.7%) for 10 urine samples.

DIET

Milk and Formula. Milk or formula was supplied to the family. During 12 balance studies two younger infants (subjects 2159 and 2179) were fed a soy isolate-based formula, supplied in ready-to-feed 8-oz glass bottles (Ross Laboratories, Columbus, OH). The formula was similar to the commercially available formula, Isomil, except that the carbohydrate was entirely maltodextrin rather than a mixture of maltodextrin and sucrose. The concentration of iron (from ferrous sulfate) was 20 mg/liter and that of added vitamin D was 400 IU/liter. The other infants were fed whole cow milk containing 400 IU vitamin D/liter supplied in quart cans (Ross Laboratories). An iron supplement (7.5 mg iron from ferrous sulfate) was added to each quart can of milk before feeding.

Beikost. Commercially prepared foods other than milk and formula were purchased by the family or provided by us. Nine different infant fruit juices were used. In study 1 some of the juices contained relatively high lead concentrations (145–327 $\mu\text{g}/\text{kg}$). These were excluded in study 2 and lead concentration of juices then ranged from 23–55 $\mu\text{g}/\text{kg}$. Five varieties of strained fruits with lead concentrations from 13–131 $\mu\text{g}/\text{kg}$ and seven varieties of strained vegetables with lead concentrations ranging from 14–73 $\mu\text{g}/\text{kg}$ were used (17).